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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : F16H 3/72, 1/46, 37/08, F03D 11/02, H02P 9/04	A1	(11) International Publication Number: WO 96/30669 (43) International Publication Date: 3 October 1996 (03.10.96)

(21) International Application Number: PCT/KR96/00042

(22) International Filing Date: 27 March 1996 (27.03.96)

(30) Priority Data:
1995/6522 27 March 1995 (27.03.95) KR

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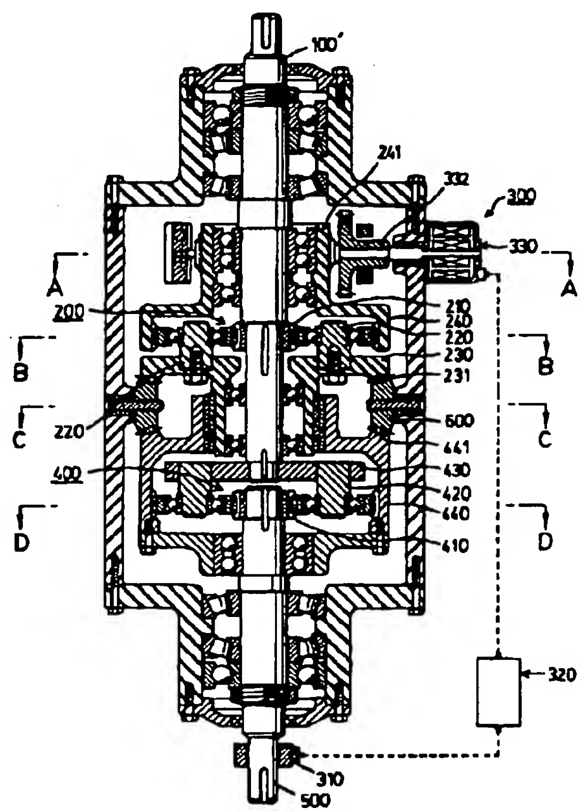
(81) Designated States: AU, BR, CA, CN, JP, NZ, RU, US, European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.

(54) Title: A VARIABLE R.P.M. CONVERTING PLANETARY GEAR SYSTEM

(57) Abstract

The present invention is to provide an advance variable-speed operation wind turbine system which overcomes the disadvantages and deficiencies of the conventional variable-speed and fixed-speed operation technology. The disclosed variable r.p.m. converting planetary gear system is designed to be used with a variable-speed operation wind turbines for the wind energy converting system which is comprised of the three mechanical configurations: an actuator control mechatronics controlled by microprocessor part (300), an actuator part (200), including three reversal transfer gears (600), and the variable r.p.m. converting part (400) of the special featured planetary gear system. The variable-speed r.p.m. input rotation force created by the varying rotor speed in accordance with wind velocity, is converted to a pre-set constant r.p.m. output force by adjusting the rotation speed and direction of the ring gear (440) of the converting system. The operational control is built up on the base of the microprocessor system with a monitoring sensor supervised the r.p.m. of input or output shaft in order to pre-set constant r.p.m. output. The system, thereby, allows to generate a high-quality mains power from variable-speed wind turbine without any power-electronic inverter system.



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DESCRIPTION

A VARIABLE R.P.M. CONVERTING PLANETARY GEAR SYSTEM

Technical Field

The present invention is related to the variable-speed operation of the wind turbine technology. With variable-speed r.p.m. input force which converts into an increasing pre-set constant-speed r.p.m. output a highly efficient mechatronic logic actuator controlled variable r.p.m. converting planetary gear system in order to generate a constant-output frequency and voltage of utility grade power output, despite the variable-speed r.p.m. input of the rotor turbine under varying wind conditions.

Background Art

Wind is one of the coldest form of energy used by man. With enormous increases in demand for environmentally friendly sources of energy, plus a growing fossil-fuel shortage, development of alternative energy sources has been stimulated.

In this same environment, wind conversion technologies are becoming more efficient and competitive, generating a high quality of electrical energy.

However, in order to meet global clean energy needs, it will be necessary to adopt a new technical approach to wind-generated electrical energy production.

There are two major challenges to a developer of a wind energy converting system : a constant-speed technology system and a variable-speed processing technology system.

The pitch control system of constant-speed wind turbines are designed to operate over a very narrow wind speed range in order to maintain constant-speed rotation for a fixed frequency of electricity produced.
However, the system should be provided with a power-electronic inverter as essential equipment for fixed frequency and constant power output, but the conventional power-electronic inverter systems deliver poor power quality with high levels of harmonics and a varying power factor.

The variable-speed technology of wind turbines can improve energy capture and reduce mechanical stress and audible noise levels caused by the varying speed of the rotor according to wind velocity. It is possible to maintain the ideal angle of attack of the blades over a wide range of wind conditions.

The present invention provides for a more cost effective and high quality of electricity producing improved mechatronic control system which is based on the prior art system patented in Korea under No. 057585 and in the United states under No. 5222924.

It should also be noted that an important feature of the invention which converts a variable-speed r.p.m input force into a constant-speed r.p.m output with an high efficiency without change to the gear ratio of the planetary gear system controlled by mechatronic logic control system.

Disclosure of Invention

The majority of wind turbines currently installed operate at constant speed through grid-connected alternators or induction generators, so that at the maximum performance coefficient Cp(max) will only occur at one wind velocity. Cp(max) : yielding a maximum power coefficient.
Therefore, to maximize the annual energy capture the rotor turbine should be provided with a innovational system for a continuos range of variable-speed

operation in all wind conditions.

Although a number of mechanical variable-systems have been tried, the majority of designs use power-electronic inverter interface. The conventional power-electronic interfaces providing the necessary frequency conversion return power to the network through Line Commutable Inverter(LCI). These deliver poor quality power with high harmonics and a vary power factor even if supply side harmonic filters are used. The present invention of the system can eliminate all of the above mentioned problems.

Referring now to the drawing, in FIG. 1 shown is a general perspective structure of the advanced wind turbine equipped with the said system and in FIG. 2 is an overall control schematic diagram of the system.

When variable-speed rotation r.p.m. increased by the main gear system 100 from the input force of rotor turbine, it is applied to the variable speed actuator 200 and the convertible r.p.m. of planetary gear device 400 via an input axle shaft 100' from the main gear 100. The actuator 200 controls the variable r.p.m. converting system 400 according to the control signal which is processed by the mechatronic governing part 300 including forward-reverse variable speed motor 330 equipped with a sensor 310 for monitoring the pre-set r.p.m. of the output axle shaft 500.

In FIG. 3 is shown a software operational flow chart which illustrated the sequence of controls. If the final output r.p.m. (Zo) meets the pre-set r.p.m. (Ro) then the microprocessor 320 controls the ring gear 440 immovable neutral position for the constant output r.p.m. $Ro=Zo$, if the output r.p.m (Zo) is higher than the pre-set r.p.m (Ro) $Ro \leq Zo$, the microprocessor 320 controls to clockwise rotation direction and the speed of ring gear 440, if the r.p.m. Zo is lower than the r.p.m. Ro $Ro \geq Zo$ the microprocessor 320 controls to counter-clockwise rotation direction and the speed of ring gear(440) by means of a mechanical processing of rotation speed and direction of the ring gear 440 of the system 400.

Brief Description of the Drawings

The present invention will be fully appreciated as it becomes better understood through detailed description of the accompanying drawings ;

FIG. 1 is a side elevational view of the multi-input propeller-type wind turbine generator containing a variable r.p.m converting planetary gear system according to the present invention.

FIG. 2 is a block diagram of the control system for the constant-speed rotating output system of the present invention.

FIG. 3 is an operational flow chart of microprocessor of the present invention.

FIG. 4 is a detailed cross sectional view of the main embodiment of the present invention.

FIG. 5 is a cross-sectional view of FIG. 4, taken along line A-A.

FIG. 6 is a cross-sectional view of FIG. 4, taken along line B-B and line D-D.

FIG. 7 is a cross-sectional view of FIG. 4, taken along line C-C.

Best Mode for Carrying Out the Invention

In reference to details regarding the illustrations of the preferred designs of the present invention, as shown in FIG. 1, FIG. 2, FIG. 3 and FIG. 4, it is comprised of :

— a multi-input rotor turbine equipped with a main gear system 100, as shown in FIG. 1 and FIG. 2, which has a vertical output axle shaft 100',

— an actuator 200 controlled by mechatronic control device 300,

— a ring gear 240, forward-reverse variable speed rotatable, being controlled by actuator motor 330 of the control part 300,

— a spider 230, forward-reverse variable speed rotatable, connected to the three planet gear members 220 which provided a respective pivotal axis,

— a spider 430, connected to the input shaft 100', consisting of three planet

gear members 420 which provided a respective pivotal axis,

— the reversal transfer gears 600 being pivotally fastened to the case 10 in order to convert the rotation direction of spider 230 and ring gear 440 or reverse,

— a ring gear 440, forward-reverse variable speed rotatable, being controlled by spider 230 of the actuator200,

— a microprocessor 320 equipped with the r.p.m. sensor 310 for monitoring the final r.p.m. of the output axle shaft 500,

— a forward-reverse variable-speed actuating motor 330 governing the rotation speed and direction of the ring gear 240 of the actuator 200 controls the rotation speed and direction of the ring gear 440.

As shown in FIG. 4, in detailed drawings, for the purpose of illustrating the preferred embodiment of the variable r.p.m. converting system in order to convert to constant-speed r.p.m. output of the present invention for use in a variable-speed rotor turbine as well as other applicable mechanical devices where need be. The possible system control methods are achieved as follows:

1). The *Output r.p.m. equals pre-set r.p.m. with* $R_0 = Z_0$

$$Z_0=\left(\frac{1+ZR}{Zs}\cdot \Delta n_1\right)+\left(\frac{ZR}{Zs}\cdot 0\cdot \Delta n_2\right) \quad \cdots\cdots\cdots\cdots\cdots\cdots \quad ①$$

R_0 : the number of output r.p.m. of pre-set constant-speed

Z_0 : the number of output r.p.m. of constant-speed.

Δn_1 : the number of input r.p.m. of variable-speed.

Zs : the number of teeth of sun gear 410.

ZR : the number of teeth of ring gear 440.

Δn_2 : the number of rotation speed and direction of ring gear 440.

0 : Zero(neutral position).

As shown in FIG. 2 and FIG. 4, variable r.p.m. Δn speed input from

the main gear system 100 is applied to the input sun gear 210 through the input axle shaft 100' in the center of the actuator 200.
Accordingly if the sun gear 210 of the actuator 200 rotates clockwise, the three planet gear members 220, connected to spider 230 are revolve around the sun gear 210 in a geared relationship with the forward-reverse rotatable ring gear 240.

When the input rotating force is applied to the spider 430, consisting of three planet gear members 420, connected to the lower end of the input axle shaft 100', which rotates in a geared relationship with the sun gear 410 and the ring gear 440 in the same direction. This effect is caused by the planet gear members 220 which are forced to revolve around the sun gear 210 counter-clockwise by load reaction rotation force from the constant r.p.m. converting system 400. Because of the rotation load reaction force from the forward-reverse rotatable ring gear 440 is applied to the spider 230 of the planet gear members 220 of the actuator 200 through the gear teeth 441 and reversal transfer gears 600 and gear teeth 231 of the spider 230.

As shown in FIG. 4 and FIG. 5 the final output speed r.p.m monitoring sensor 310, positioned around the output axle shaft 500, sends a $R_0=Z_0$ signal to the microprocessor 320, which processes the signal $R_0=Z_0$ to the control mechatronic variable-speed forward-reverse actuating motor 330 of the actuator 300, which being connected to the control gear(332) connected to the rotor shaft 331, which rotates in a geared relationship with the activating gear 333. This activating gear 333 is equipped with a horizontal rotor shaft 334, connected to the worm gear 340 which rotates in a geared retationship with worm-wheel-gear 350 connected to the extender 241 which extended from the ring gear 240 of the actuator 200.

However, if the spider 230 of the planet gear members 220 of the actuator 200 is forced to revolve around the counter-rotation of input sun gear 210 by the load reaction force, as previously described, is to be controlled in

balance to immovable neutral position by the speed of the ring gear 240 of the actuator 200 through the actuating motor 330 of actuator control system 300.

As a result the variable r.p.m. converting planetary gear system 400, operates as a normal operation planetary gear in principle, thus the input r.p.m. force is applied to the spider 430 of the planetary gear numbers 420 through the input axle shaft 100′ with an immovable neutrally positioned ring gear 440. The output sun gear 410 rotates at the speed of pre-set constant-speed r.p.m. of the converting system 400, which is consistent with the equation ①.

2) The *Output r.p.m. is higher than the pre-set r.p.m. with $R_0 \leqq Z_0$.*

$$Z_0 = \left(\frac{1+ZR}{Zs} \cdot \Delta n_1 \right) + \left(\frac{ZR}{Zs} \cdot -\Delta n_2 \right) \quad \cdots\cdots\cdots\cdots\cdots\cdots \quad ②$$

$-\Delta n_2$: a number of clockwise rotation of ring gear(440)

As shown in FIG. 2 and FIG. 4, when a variable speed r.p.m. Δn input with $R_0 \leqq Z_0$, from the main gear system 100 is applied to the input sun gear 210 positioned in the center of the actuator 200 through the input axle shaft 100′, the input sun gear 210 rotates in a geared relationship with the three planet gear members 220 and the ring gear 240 of the actuator 200.

If with a gust of wind, an over speed variable r.p.m. is applied to the said gear system 400, and the output sun gear 410 rotates with a higher speed than the pre-set r.p.m., the output speed monitoring sensor 310 attached to the output axle shaft 500 activates to send a $R_0 \leqq Z_0$ signal to the microprocessor 320 as shown in FIG. 2, FIG. 3, FIG. 4 and FIG. 5. The microprocessor 320 compares the signal $R_0 \leqq Z_0$ with the pre-set r.p.m. sends a control signal to the mechatronic variable-speed actuating motor 330, and then the actuating motor 330 will accelerate the rotation speed to control counter-clockwise rotation of the ring gear 240 so as to adjust counter-colckwise rotation to the

speed of the spider 230 (the load reaction rotation force is applied to the spider 230 counter-clockwise).

The rotation force of the spider 230 is transmitted via reversal transfer gears 600 and is applied to the ring gear 440 which rotates at the neutral position in the clockwise direction of the variable r.p.m. converting system 400, which is consistent with the equation ②. Consequently, both one-way rotation direction of the pivotally forward-reverse rotatable ring gear 440 and the spider 430 connected to the input axle shaft 100' can be adjust the r.p.m. to meet the pre-set constant output r.p.m. of the output axle shaft 500.

3) The *Output r.p.m. is lower than the pre-setting r.p.m. with* $R_0 \geqq Z_0$.

$$Z_0 = \left(\frac{1+ZR}{Zs} \cdot \Delta n_1 \right) + \left(\frac{ZR}{Zs} \cdot \Delta n_2 \right) \quad \cdots\cdots\cdots\cdots \quad ③$$

$+\Delta n_2$: the number of counter-clockwise rotation of ring gear 440

As shown in FIG. 2 and FIG. 4, when a variable lower speed r.p.m. Δn input with $R_0 \geqq Z_0$, from the main gear system 100 is applied to the input sun gear 210 positioned in the center of the actuator 200 through the input axle shaft 100' and the input sun gear 210, these gears rotate in a geared relationship with three planet gear members 220 and the ring gear 240 of the actuator 200. The lower speed r.p.m. due to weak wind conditions, is also taken into account in the above mentioned gear system 400. The output sun gear 410 rotates with a lower speed r.p.m. than the pre-set r.p.m., thereby the activating output speed monitoring sensor 310 to send a $R_0 \geqq Z_0$ signal to the microprocessor 320, as shown in FIG. 2, FIG. 3 and FIG. 4. The microprocessor 320 compares the signal $R_0 \geqq Z_0$ with the pre-set r.p.m. and processed to send a control signal to the actuating motor 330. The actuating motor 330 controls the revolving speed of the spider 230 through the ring gear 240 of the planet gear

member 220 in order to rotate in a clockwise at the immovable neutral position.

As above described the rotation force is transmitted via the reversal transfer gears 600 and is applied to the ring gear 440 which rotated at the immovable neutral position in the counter-clockwise direction. Thus, the constant r.p.m. of the output axle shaft 500 can be controlled by the rotation speed and direction of the ring gear 440, which is consistent with the equation ③.

As described previously, the variable r.p.m. converting system of the present invention is applicable to the various industrial fields.

Numerous modifications and variations of the present invention are possible : a series or parallel connection of multiple control gear devices and motors, either the input or the output r.p.m. monitoring sensor devices or both of them, and the mechanical structures of the actuator as well as the mechatronic control devices. All such modifications as would be obvious to one skilled in the art are to be included within the scope of this invention as defined by the following claims.

What is claimed is:

1. A variable r.p.m. converting planetary gear system comprising:

a) A variable-speed r.p.m. input axle shaft 100',

b) An actuator 200 including an input sun gear 210 fixed to the surface of said input axle shaft 100', a plurality of planet gear members 220, a forward-reverse variable speed rotatable spider 230 and a forward-reverse rotatable ring gear 240,

c) A mechatronic control means 300 connected to said forward-reverse ring gear 240 to control the rotation speed and the direction of said forward-reverse ring gear 240,

d) A constant r.p.m. of planetary gear means 400 including an output spider 430 fixed to the lower part of said input axle shaft 100', rotatable planet members 420 connected to said out spider 430, a ring gear 440 in geared relationship with said input spider 230 and an output sun gear 410 positioned inside and to rotate in geared relationship with said rotatable planet members 420,

e) An output axle shaft 500 fixed in the center of said output sun gear 410.

2. The variable r.p.m. converting planetary gear system according to claim 1 wherein said forward-reverse spider 230 and said ring gear 440 are equipped with gear's teeth 231, 441 in geared relationship with each other, through transfer gears 600 pivotally fastened to the case 10.

3. The variable r.p.m. converting planetary gear system according to claim 1 or 2 wherein said mechatronic control means 300 comprises a

sensor 310 monitoring the rotation r.p.m. the output axle shaft 500, a microprocessor 320 to process the rotation speed and direction of said mechatronic control means 300, a forward-reverse variable-speed actuator motor 330 which is rotating in the speed and direction being controlled by said microprocessor 320, a forward-reverse rotatable worm gear 340 and a worm-wheel-gear 350 formed on the outer surface of said ring gear 240.

4. The variable r.p.m. converting planetary gear system according to claim 3 wherein a control gear 332 is fixed to the rotor schaft 331 of said actuating motor 330 connected to the actuating gear 333 in geared relationship, and said rotatable worm-gear 340 is fixed to the axle shaft 334 and in geared relationship with the worm-wheel-gear 350.

FIG. 1

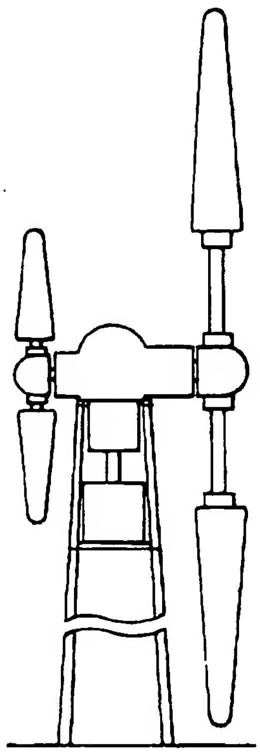


FIG. 2

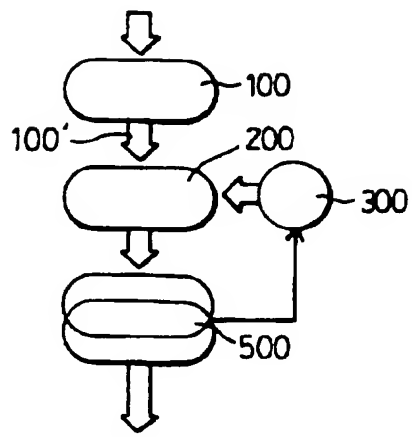


FIG. 3

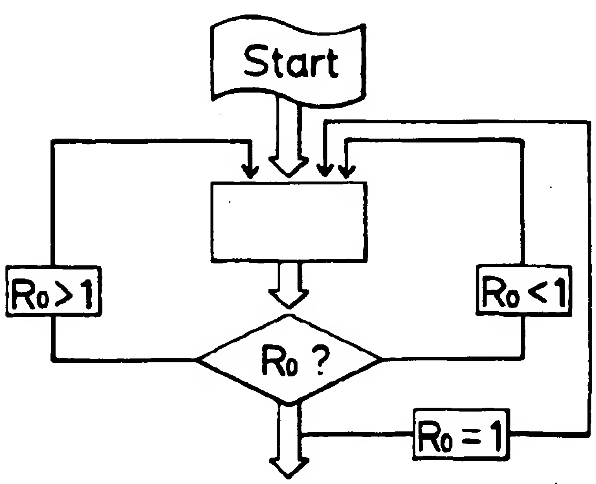
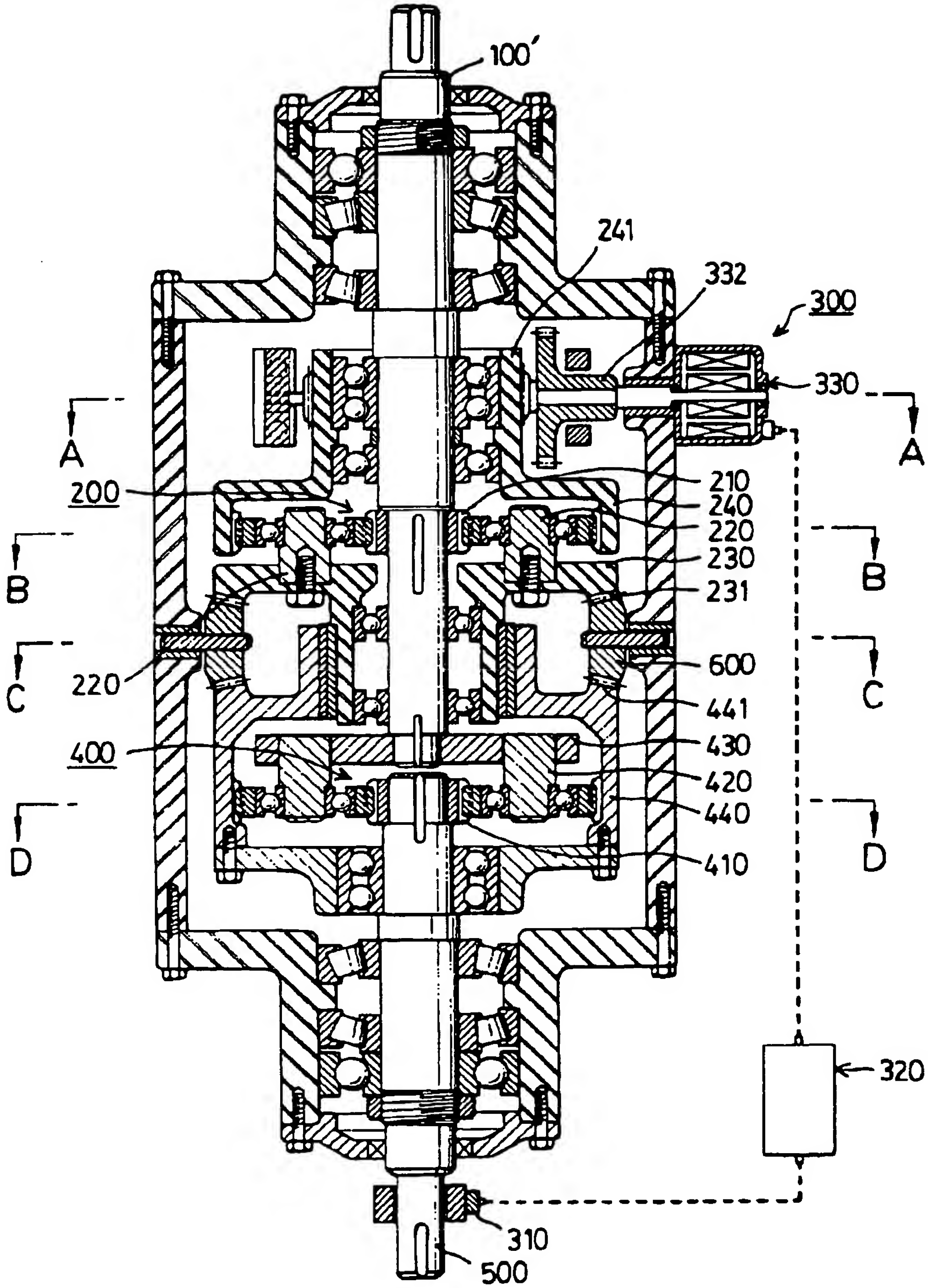


FIG. 4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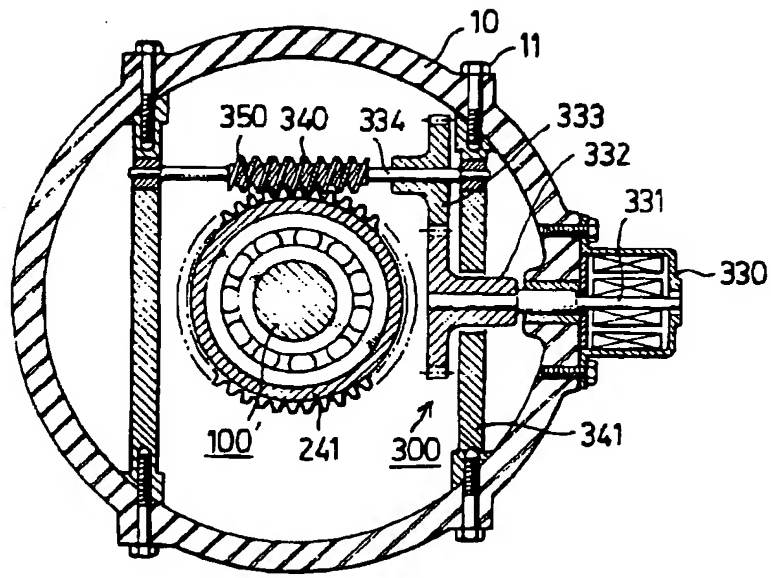
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FIG. 6

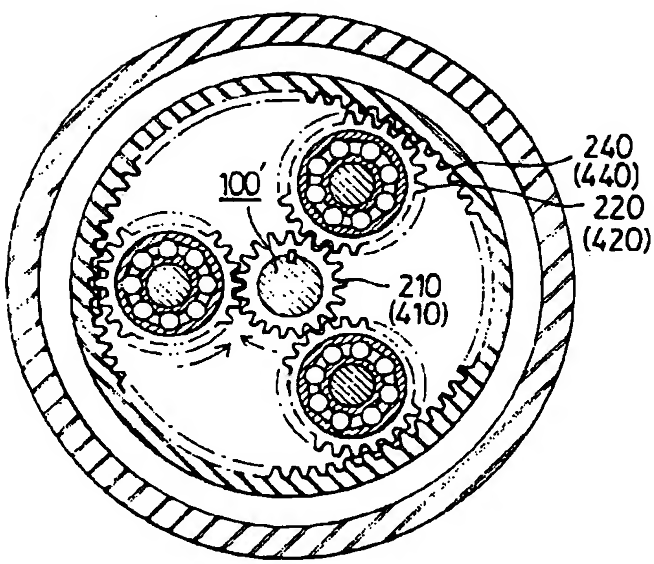
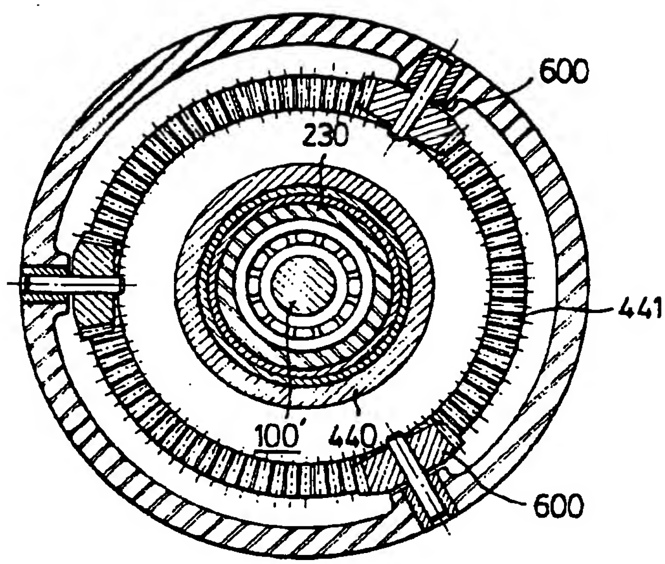

240
(440)
100′
220
(420)
210
(410)

FIG. 7



INTERNATIONAL SEARCH REPORT

International application No.
PCT/KR 96/00042

A. CLASSIFICATION OF SUBJECT MATTER

IPC^6: F 16 H 3/72,1/46,37/08; F 03 D 11/02; H 02 P 9/04

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

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A	JP 6-200 864 A (KAWATETSU) 19 July 1994 (19.07.94), totality.	1-4
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A	WO 81/01 444 A1 (ALLMÄNNA) 28 May 1981 (28.05.81), totality.	1-4
A	WO 91/19 916 A1 (HICKS) 26 December 1991 (26.12.91), totality.	1-4
A	US 4 513 206 A (GERVASIO) 23 April 1985 (23.04.85), totality. ----	1-4

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Date of the actual completion of the international search	Date of mailing of the international search report
22 May 1996 (22.05.96)	07 June 1996 (07.06.96)

Name and mailing address of the ISA/AT	Authorized officer
AUSTRIAN PATENT OFFICE Kohlmarkt 8-10 A-1014 Vienna Facsimile No. 1/53424/535	Werdecker Telephone No. 1/53424/361

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/KR 96/00042

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